Wind and Seismic Effects

Proceedings of the 30th Joint Meeting

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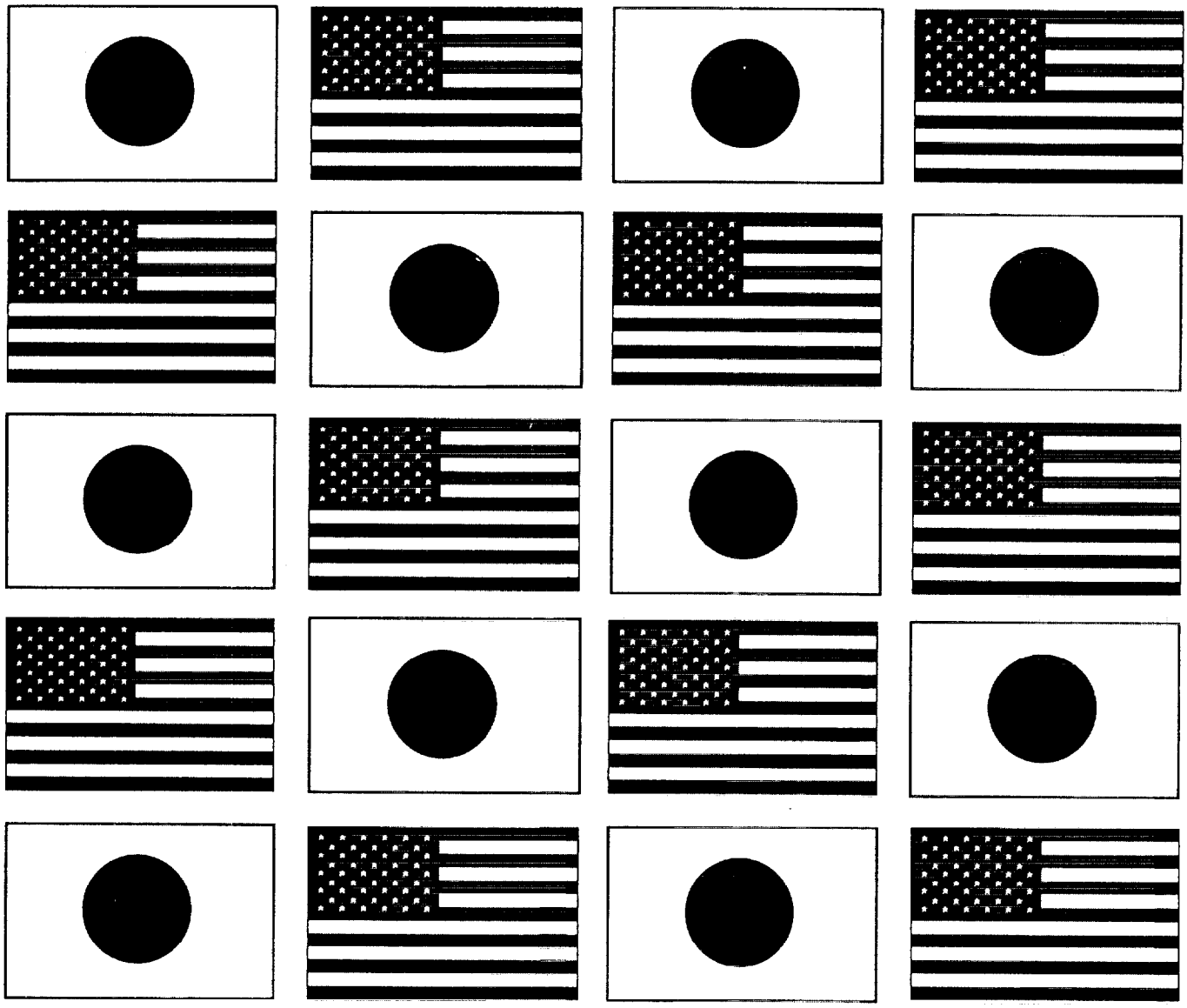

U.S. DEPARTMENT OF COMMERCE
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Wind and Seismic Effects

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EARTHQUAKE ENGINEERING

A Vision for the Future of Strong-Motion Recording

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ABSTRACT

Strong-motion recordings of shaking are the basis for earthquake resistant design, construction, and retrofit practices worldwide. They provide critical quantitative measurements of damaging earthquakes in urban environments needed for mitigation of future earthquake losses. The present critical lack of strong-motion information emphasizes that urgent action is required to significantly increase resources to adequately record future damaging earthquakes. Recent estimates for the US suggest that an urgent need to record the next major earthquake adequately throughout stricken urban areas requires that instrumentation and recording efforts be increased by nearly 20 times within the next five to ten years (Stepp, 1997; Borcherdt, et al., 1997). Justification for this dramatic increase as prepared by the "Committee for the Future of the US National Strong-Motion Program" (Borcherdt, ed., 1997) is summarized here.

1. INTRODUCTION

Staggering losses from recent earthquakes impacting Northridge, California ($15 to $25 billion, 64 lives) and Kobe, Japan (> $100 billion and 5500 lives) clearly demonstrate the potential impact of moderate to large earthquakes on modern urbanized societies. If a major earthquake impacted some densely urbanized areas of the United States in the near future, life and economic losses are estimated to be at least twice as large. If these same earthquakes were to impact the areas in thirty to fifty years without any major changes in earthquake safety, losses could reach tens of trillions of dollars due to increased urbanization with inadequate safety standards. These tremendous potential losses with catastrophic and global consequences argue strongly for dramatically accelerated programs to improve public earthquake safety as quickly as resources permit.

Reduction of life and property losses to low and manageable levels requires significant improvements in both *Hazard Mitigation* and *Emergency Response*. Quantitative measurements of strong shaking referred to as "strong-motion recordings" are the critical and presently scarce element essential for significant progress in both areas. Modern technology offers important new opportunities to acquire these recordings.

This paper provides a brief summary of the justification for the need to significantly increase strong-motion observation for public safety. The application of the limited existing set of strong-motion information to earthquake hazard mitigation worldwide suggests that arguments for additional information need to be considered in international forums. This summary is presented here to further evaluate the need for strong-motion observation worldwide. The summary is presented as a series of answers to specific questions prepared by the "Committee for the Future of the US National Strong-Motion Program", (Borcherdt, ed., 1997).

KEYWORDS: Strong-motion recording, Public Earthquake Safety, Earthquake hazards reduction, Emergency response, Strong motion.

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2. How significant is the earthquake threat to public safety?

- Staggering losses from recent earthquakes impacting Northridge, California ($15 to $25 billion, 64 lives) and Kobe, Japan (> $100 billion and 5500 lives) clearly demonstrate the potential impact of moderate earthquakes on modern urbanized societies.
- Dramatic increases in urbanization based on inadequate safety standards imply that costs in lives and property from a future major earthquake in the United States could exceed $200 billion dollars, cause several thousand deaths, and significantly impact the global economy.

3. What are strong-motion recordings?

- Strong-motion recordings are on-scale recordings of the main damaging earthquake at locations of most significance for public earthquake safety.
- Strong-motion recordings are recordings of the main shock, often on or near structures in densely urbanized environments, within 20 km of the earthquake-rupture zone for sites on rock and within about 100 km for sites on soft soils. Recordings of motions at levels sufficient to cause damage at sites at greater distances also are of interest for earthquake engineering in areas likely to be affected by large subduction zone earthquakes or in areas with exceptionally low attenuation rates.

4. Why are strong-motion recordings critical for significant improvements in public safety?

- Public safety requires that man-made structures resist strong, earthquake-induced shaking.
- Strong-motion recordings are the quantitative in-situ measurement of shaking and the resultant dynamic performance of structures needed to build and strengthen the built environment to resist future earthquakes.
- Strong-motion recordings are the basis for all current earthquake-resistant design, construction, and retrofit codes and practice.
- Strong-motion recordings are the basis for a significant proportion of the research products produced for purposes of earthquake hazard reduction.
- Strong-motion recordings are necessary for real-time damage assessment and emergency response in densely urbanized areas as both efforts require dense sets of on-scale measurements of damaging levels of shaking on and near structures in earthquake stricken areas.
- The present scarcity of quantitative measurements of ground shaking and its damaging effects on the built environment is a **major obstacle** to reducing future losses of life and property to manageable levels.

5. Why is the present set of US strong-motion recordings inadequate?

- No recordings exist of any major (M_w> 7.5) US earthquake at locations experiencing damaging levels of shaking.
- No recordings of any high-rise, steel-moment-frame building within 20 km of a moderate to large (M_w> 6.5) US earthquake exist.
- No recordings exist in the US of any critical lifeline at damaging levels of motion, such as the six major bridges crossing the San Francisco Bay that are being presently retrofitted, based on as yet undocumented levels of ground shaking.
- Few (<10) recordings of the dynamic response of soft soils exist, yet billions of dollars of bridges, buildings, pipelines, and highways are being built on such deposits each year.
- Few (<10) recordings exist of large sudden coherent pulses of motion ("fault fling" or "killer pulses") that occur near the fault rupture and are expected to cause catastrophic losses for cites such as Hayward, Oakland and Berkeley, CA.
- Few recordings of most modern structures in their in-situ environment have been obtained of actual damaging levels of earthquake loading.

6. Why is a thorough set of strong-motion recordings of the next damaging earthquake an urgent national need?

- Billions of dollars are being expended each year to build and strengthen the built environment based in many cases on as yet undocumented strong ground shaking and structural performance levels.
- If thorough sets of strong-motion recordings of the next major earthquake are not obtained on and near structures in the stricken areas, then another important infrequent opportunity will be missed.
- Present expenditures based on a totally inadequate database will continue and the catastrophic costs of future earthquakes will increase exponentially with time as urbanization increases.
- The high likelihood for a major damaging earthquake to strike areas such as the San Francisco Bay region within the next five years, implies an urgent effort is required to acquire and install the necessary resources to prevent another major missed opportunity.

7. What resources are required to provide an adequate set of strong-motion recordings of the next major earthquake in the coterminous United States?

- Recent consensus of a national workshop (Stepp, 1997) implies a dramatic increase in resources (funding and people) is needed to ensure that critically needed instrumentation (20,000 stations) is operational by the year 2005.
- Estimates derived on the basis of recent National Seismic Hazard Maps (Frankel, et al., 1996) and estimates of population exposure imply that instrumentation at about 20,000 sites is needed with 7,000 for ground-motion, 7,000 for buildings, 3,000 for lifelines, such as bridges and pipelines, and 3,000 for critical facilities necessary for emergency response and near-real time disaster assessment (Borcherdt, 1997a, 1997b, Borcherdt, et al., 1997).

8. What resources are required to record a specific earthquake in one of the areas with high population exposure to damaging ground motions?

- Estimates of the density and location of strong-motion stations needed to record a specific earthquake can be developed for each urban area using modern GIS technology, regional estimates of ground shaking, inventories of the built environment, and modern methods to predict resultant earthquake losses.
- Application of the procedures to the San Francisco Bay Region for a repeat of the 1906 earthquake (Mw 7.7) provides significant insight for strong-motion planning purposes.
- Estimated losses for a repeat of the 1906 earthquake are expected to exceed $200 billion with more than 5000 deaths (RMS, inc., 1995).
- 140 - 180 ground-motion stations are needed in the city of San Francisco with a spacing of no more than a few blocks in the heavily impacted financial district.
- Superposition of the built environment on predicted ground shaking maps shows that in the southern San Francisco Bay region 45% of the 1079 bridges, 69% of the 16 airports, 22% of the 233 hazardous material sites, 48% of the 99 medical facilities, and 48% of the 801 schools are located in areas expected to experience damaging levels of shaking that exceed 0.6 g in spectral response acceleration at 1.0 second.
- Superposition of the transportation facilities on a site class map based on the 1994 Recommend Building Code provisions shows that 69% of the bridges, 57% of the highways, and 100% of the railways are located on either stiff clays and sandy soils or on soft clays with a high to very high amplification capability and moderate-to-high liquefaction susceptibility.
- The large percentages of important structures (~ 990) and buildings (>3000) located in areas of potentially damaging ground shaking

suggest that more than 4000 sites in the SF Bay region need to be considered for instrumentation.

- If only 10 percent of especially vulnerable structures in the southern SF bay region are instrumented, then at least 400 instrumentation arrays on and near structures are needed.
- Instrumentation estimates show that the present level of strong-motion instrumentation in the densely urbanized areas of the San Francisco Bay Region is woefully inadequate to document the ground shaking and the resultant seismic performance of the built environment to a repeat of the 1906 earthquake.

9. What proportion of strong-motion stations should be equipped with real time telecommunication for purposes of disaster assessment and emergency response?

- Modern instrumentation with telecommunication capabilities permits areas of strongest shaking and the performance of structures to be quickly assessed (Nigbor, 1997). Instruments on structures such as major buildings, hospitals, schools, bridges, freeway overpasses, dams etc. permit rapid assessment of probable damage state, efficient dispatch and routing of emergency response resources, and efficient prevention of additional disaster. Several important examples illustrating the application of modern technology to Disaster Reduction now exist in Japan.
- Preliminary estimates on the basis of estimated shaking levels suggest that some 50-85% of the strong-motion instrumentation installed for ground-motion measurement purposes in cells of highest population exposure should be equipped with near-real time communication capabilities for at least some channels.
- Considerations based on the geographic distribution of the built environment for the southern San Francisco suggest some 25 to 50 percent of instrumented structures should also be equipped with telecommunication for a few data channels to assess the damage state of the structures in near-real time.

10. CONCLUSION

Strong-motion recordings of shaking are the basis of earthquake resistant design, construction, and retrofit practice. For many issues important in earthquake safety, advances will not occur until a major earthquake provides new strong-motion data. It is vital that we plan wisely to obtain the greatest possible return from the next earthquake, so that societies will not be forced to wait for another disaster before acquiring the needed data to resolve important safety issues.

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